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(54) Title: METHOD FOR GENERATING A CORRECTED ERROR SIGNAL, AND CORRESPONDING APPARATUS
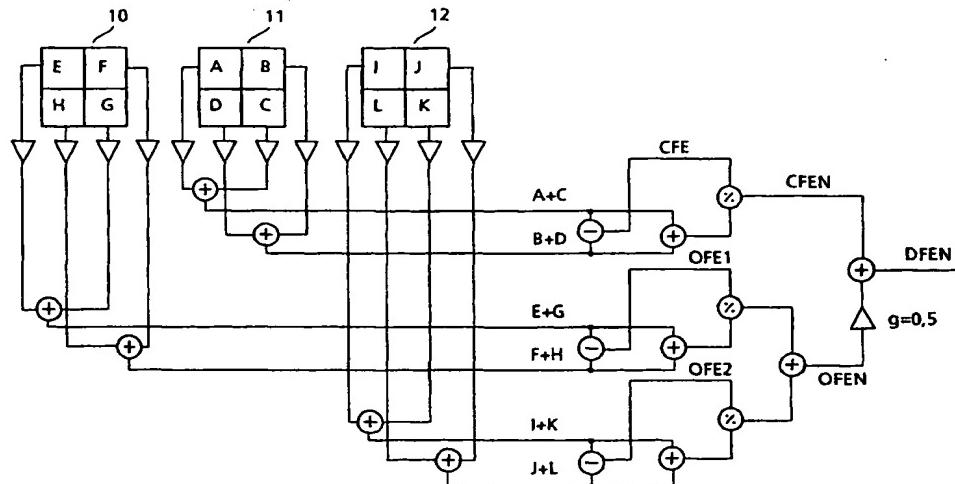
(57) Abstract: In order to obtain a corrected or compensated focus error signal (DFEN) or track error signal (DPPN), it is proposed to generate primary and secondary scanning beams incident on adjacent tracks of an optical recording medium (7) and to detect the primary and secondary scanning beams reflected from the optical recording medium in order to derive from them primary-beam and secondary-beam focus error signals (CFE, OFE) or primary-beam and secondary-beam track error signals (CPP, OPP), which are subsequently normalized in order to obtain the compensated focus error signal (DFEN) or track error signal (DPPN) from the normalized primary-beam and secondary-beam error signals (CFEN, OFEN; CPPN, OPPN) by means of weighted combinations. As a result of the normalization, the corrected or compensated focus error signal (DFEN) or track error signal (DPPN) is generated independently of the reflection properties of the respectively scanned track.

Method for generating a corrected error signal, and corresponding apparatus

The present invention relates to a method for generating
a corrected error signal, in particular an offset-
compensated focus error signal or track error signal, for
an apparatus for reading from and/or writing to an
optical recording medium according to the preamble of
Claim 1, and also to a correspondingly configured
apparatus according to the preamble of Claim 16.

One of the widespread methods for forming a focus error
signal is the so-called astigmatism method. This method
can be used if only one type of track is intended to be
scanned or there is minor interaction between the type of
track region scanned and the focus error signal. Optical
storage media in which information tracks are contained
both in depressions, referred to as "groove", and in
elevations, referred to "land", have different focus
offsets during the focus error signal generation
according to the traditional astigmatism method during
the scanning of information tracks in tracks with
depressions and tracks with elevations. The asymmetries
of the track geometry (width ratios, flank slope of the
track edges, etc) may be regarded as a reason for this.

The problems associated with the conventional method will
be explained in more detail below.

The focus error signal is conventionally generated for
example according to the DFE method ("Differential Focus
Error"). When the DFE method is employed, the laser beam
of an optical scanner comprises three beams, namely a
primary beam and two secondary beams which scan adjacent
tracks of the respective optical storage medium or
optical recording medium. The primary and secondary beams
reflected from the optical recording medium are evaluated
in order to obtain, in a manner dependent thereon,

primary-beam and secondary-beam focus error signals from
which the desired focus error signal is generated by
means of a weighted combination. In order to achieve the
splitting into three beams, an optical grating is
5   inserted into the beam path of the light source.

Figure 5 illustrates a corresponding arrangement. The
light emitted by a light source or a laser 1 passes
through a collimator lens 2 and is then split into the
10 primary beam (i.e. a 0th-order beam) and the two
secondary beams (i.e. ± 1st-order beams) by a diffraction
grating 3. The primary beam, which reads the information
to be scanned in a track of a corresponding optical
recording medium 7, usually contains the majority
15 (approximately 80-90%) of the light information. The two
secondary beams each contain the remaining approximately
5-10% of the total light intensity, it being assumed for
the sake of simplicity that the light energy of the
higher orders of diffraction of the grating 3 are zero.
20 These three beams are focussed onto the optical recording
medium 7 via a polarizing beam splitter 4 and a quarter-
wave plate 5 and also an objective lens 6, in order to
read from and/or write to the said optical recording
medium. The three beams reflected from the optical
25 recording medium 7 are fed via the beam splitter 4 and a
cylindrical lens 8 to a photodetector unit 9, which
detects the three beams reflected from the optical
recording medium 7. Connected to the photodetector unit 9
is an evaluation circuit 16 which evaluates the detected
30 reflected primary and secondary beams for the purpose of
generating a focus error signal. Primary and secondary
beams are spatially separate from one another only in the
focussed or virtually focussed state, so that they are
illustrated as a common beam pencil in the figure.
35

As is illustrated in Figure 6 using a DVD-RAM as optical
recording medium 7, the optical grating 3 is constructed
in such a way that the imaging of the two secondary beams

13 and 15 scans precisely the centre of the secondary
tracks or (in the case of media which can be written to
only in "groove" tracks) the centre beside the track
scanned by the primary beam 14. Figure 6 also illustrates
5   an example of the scanning of optical recording media,
for example a CD-ROM or DVD-ROM, having so-called "pits"
50, the direction of rotation of the optical recording
medium being indicated in each case by the arrow in
Figure 6. Only a very small detail from the information-
10   carrying layer of the recording medium 7 is illustrated
in each case in a diagrammatic illustration. The tracks
designed as depressions are designated by "groove" or Gr
and simply shown hatched, while the tracks designed as
elevations are designated by "land" or La and are not
15   hatched. In the right-hand part of Figure 6, the tracks
provided   with   information   are   provided   with
diagrammatically illustrated pits, i.e. depressions or
markings which influence a beam property in some other
way.
20

Since the secondary beams 13 and 15 and the primary beam
14 are intended to be optically separable from one
another, the positions of their imaging on the optical
recording medium 7 and on the photodetector unit 9 are
25   separate from one another. If the optical recording
medium 7 rotates, then one of the secondary beams is
situated in front of, and the other secondary beam
behind, the primary beam in the reading or writing
direction.
30

Considered by themselves in each case, both the primary
beam and the secondary beams generate, on the
correspondingly chosen photodetector unit 9 and after
subsequent suitable combination of the detector signals,
35   a primary-beam and, respectively, secondary-beam focus
error signal which represents the focus error of the
respective beam with respect to the scanned surface of
the optical recording medium 7. However, since the two

secondary beams scan the two secondary tracks with respect to the actual read/write track (and hence the inverted position "groove"/"land"), the focus offset error of the secondary beams is inverted relative to the focus offset error of the primary beam. Consequently, considered by themselves, the respective focus error signals in each case contain the actual focus error with respect to the illuminated surface and also oppositely oriented track-position-dependent focus offset components.

In order to illustrate these facts, Figures 8A and 8B illustrate the detection of the primary and secondary beams reflected from the optical recording medium 7 using the example of a photodetector unit 9, having three multi-zone photodetectors 10-12, the two photodetectors 10 and 12 each being provided for detection of a secondary beam, while the photodetector 11 serves for detection of the reflected primary beams. Each photodetector 10-12 has four photodetector elements, designated by E-G, A-D and I-L, respectively. This designation will also be used hereinafter for referring to the output signals generated by the corresponding photodetector elements. Figure 8A illustrates the example of a photodetector image given the presence of a track-position-dependent focus offset component without focus error, while Figure 8B illustrates the example of a photodetector image with focus error but without track-position-dependent offset.

If the focus error signals of the secondary beams are then added and this sum is in turn added to the focus error signal of the primary beam, these undesirable focus offset components cancel one another out given appropriate weighting between the primary and secondary beam components. Since the focus error components of primary and secondary beams are synchronous relative to one another, these are added in the correct phase.

Consequently, given correct setting of the weighting factor, all that remains is the actual focus error without a track-position-dependent focus offset component.

In this case, however, it must be taken into account that the amplitude of the focus error contribution of each scanning beam is proportional to the average reflection of the respectively scanned track of the optical recording medium. Therefore, the functioning of the previously described procedure presupposes that the intensity ratios between the primary beam and the secondary beams do not change relative to one another, in order to be able to set a specific weighting factor for compensation purposes. Herein lies the problem of the previously described method, however. If an optical recording medium that has been written to completely is read, then the reflection properties of the "groove" and "land" tracks (for example in a DVD-RAM) are identical. It can then be assumed, in a simplification, that the undesirable track-position-dependent offset components and also the desired focus error components of the three scanning beams each have the same magnitude. Presupposing this, it is possible to find a weighting factor which provides for complete compensation of the track-position-dependent focus offset components.

If, however, as is shown in Figure 7, a hitherto blank optical recording medium, or one which has been recorded on only in part, is written to, then the primary beam used for writing alters the reflection properties of the storage medium on the tracks currently written to. If a "groove" track is written to in a DVD-RAM disc, for example, then only the reflection property of this track changes in the course of writing. The reflection properties of the "land" secondary tracks remain unaltered. This means that the weighting factor used hitherto no longer leads to compensation of the track-

6

position-dependent focus offset components. The weighting
factor is likewise no longer valid for a case in which
the primary beam scans a written-to track and one of the
two secondary tracks has been written to but the other

5   has not. Since the sectors of a DVD-RAM disc do not have
to be written to continuously, problems can thus already
arise during the scanning of such a disc if the
reflection properties of the track read and the secondary
tracks differ from one another. In order to illustrate

10   this problem, Figure 7 illustrates the unwritten parts of
the "groove" or "land" tracks, which have different
reflection properties from the written parts, hatched
from top left to bottom right. The groove tracks, which
are identified by hatching anyway, are thus doubly

15   hatched in the written region, while the land tracks are
not hatched in the unwritten region.

These problems can likewise occur in storage media on
which information is stored only in "groove" tracks. When

20   a storage medium of this type is written to, the
reflection of the written track likewise changes. Since
only "groove" tracks are written to, in theory the
reflection properties of the regions between the tracks
do not change as a result of the "groove" track being

25   written to. In practice, however, owing to the small
track spacings on the storage medium, there are also
influences of the writing primary beam on the reflection
of the regions directly beside the primary track. This
means that the beam leading to the primary beam and the

30   beam following the primary beam scan regions between the
tracks which have different reflection properties.

Thus, in the case of the two types of optical recording
media described above, it is not possible to set a

35   generally valid weighting factor which enables complete
compensation of the track-position-dependent focus offset
component. Although in theory it is possible to determine
and store different settings for the weighting factor on

the basis of the different properties of the respectively
scanned track regions, it would then be necessary, with
corresponding complexity, at all times to determine the
state of the instantaneously scanned region and to set
5   the appropriate weighting factor. However, in particular
in the case of track jumps and imperfections of the
storage medium to be read from or written to, this can
lead to insoluble problems since the currently scanned
region of the storage medium then cannot be reliably
10   ascertained.

A similar problem occurs when generating a track error
signal.

15   The track error signal is conventionally generated for
example according to the so-called DPP method
("Differential Push-Pull"), as is described for example
in the publication "Land/Groove Signal and Differential
Push-Pull Signal Detection for Optical Disks by an
20   Improved 3-Beam Method", Ryuichi Katayama et al.,
Japanese Journal of Applied Physics, vol 38 (1999), pages
1761-1767. When the DPP tracking method is employed, too,
the original laser beam is split into three beams, namely
a primary beam and two secondary beams which scan
25   adjacent tracks of the optical recording medium
respectively used. As shown in Figure 5, the primary and
secondary beams reflected from the optical recording
medium are detected by a photodetector unit 9 and
evaluated by an evaluation circuit 16 in order to obtain
30   the track error signal. In the process, considered by
themselves in each case, both the primary beam and the
secondary beams generate a push-pull signal which
represents the track error of the respective signal with
regard to the respectively scanned track. However, since
35   the two secondary beams scan the secondary tracks with
respect to the read/write track, their push-pull error is
inverted with respect to that of the primary beam.
Considered by themselves, the respective push-pull

components thus contain the actual track error with respect to the respectively scanned track. Since the track position of the three beams can only change together, the three push-pull signals change equally.

5

If the objective lens 6 is then moved in the track direction, the imaging of primary and secondary beams on the photodetector unit 9 also moves. This displacement of the imaging results in an offset voltage at the output of the photodetector unit 9. The direction of this offset voltage is identical for all of the beams. The displacement of the objective lens 6 thus gives rise to an offset voltage which does not originate from an actual track error and is therefore an interference. The genuine track error component and the undesirable lens-movement-dependent component are added in the push-pull signal yielded by the respective detectors of the photodetector unit 9.

For illustration purposes, Figure 10A illustrates a photodetector image with push-pull, while Figure 10B illustrates a photodetector image with spot movement. In both illustrations, it is assumed that the photodetector unit 9 has three photodetectors 10-12, the photodetector 11 detecting the primary beam reflected from the optical recording medium 7, while the other two photodetectors 10 and 12 detect the reflected secondary beams. Furthermore, it is assumed that the photodetector is a four-quadrant detector (also cf. Figure 8), while the two photodetectors 10 and 12, which serve for detection of the reflected secondary beams, merely have two photodetector elements E1 and E2, and, respectively, F1 and F2.

If the signals yielded by the photodetectors 10 and 12 are then added and this summation signal is subtracted from the signal of the photodetector 11 which detects the reflected primary beam, then the previously described

lens-movement-dependent component is cancelled out given appropriate weighting between the primary and secondary beam components. However, since the push-pull components of primary and secondary beams are inverted with respect

5   to one another, they are added in the correct phase after application of the subtraction. Consequently, given correct setting of the weighting factor, all that remains is the actual track error.

10 The previously described procedure for determining a corrected or compensated track error signal is thus similar to the abovementioned procedure for determining a compensated or corrected focus error signal. In the case of determining the corrected track error signal, too,

15 however, the functioning of this method presupposes that the intensity ratios between primary beams and secondary beams do not change relative to one another.

If an optical storage medium that has been written to

20 completely is read, then the reflection properties of the "groove" tracks or "land" tracks are identical in the case of a DVD-RAM recording medium. Consequently, it is possible to find a weighting factor which provides for complete compensation of the lens-movement-dependent

25 components.

If, however, a hitherto blank optical medium is written to, then the primary beam used for writing alters the reflection properties of the optical storage medium on

30 the tracks currently written to. If a "groove" track is written to on a DVD-RAM disc, for example, then only the reflection property of this track changes in the course of writing. The reflection properties of the "land" secondary tracks remain unaltered. This means that the

35 weighting factor used hitherto no longer leads to the compensation of the lens-movement-dependent component. The weighting factor is likewise no longer valid if the primary beam scans a track that has already been written

to, and one of the two secondary tracks has been written to, while the other has still not been written to. Since the sectors of a DVD-RAM disc, for example, do not have to be written to continuously, problems can thus already

5   arise during the scanning of such a disc if the reflection properties of the track read and of the secondary tracks differ from one another.

These problems can likewise occur in the case of storage

10 media in which information is stored only in "groove" tracks. When a storage medium of this type is written to, the reflection property of the written-to track likewise changes. Since only "groove" tracks are written to, in theory the reflection properties of the regions between

15 the tracks do not change as a result of the "groove" track being written to. In practice, owing to the small track spacings on the optical recording medium, there are also influences of the writing primary beam on the reflection of the regions situated directly beside the

20 primary track. This means that the secondary beam leading the primary beam and the secondary beam following the primary beam read different reflection properties of the regions between the individual tracks.

25 Consequently, in the case of the two types of optical recording media described previously, it is not possible to set a generally valid weighting factor which achieves complete compensation of the lens-movement-dependent component.

30

EP 0 788 098 A1 proposes generating a track error signal or a focus error signal from the output signals of a photodetector having multi-zone detector elements, the track error signal or focus error signal, after being

35 generated, being divided by a summation signal composed, inter alia, of all the output signals of the individual photodetector elements. In this way, normalization of the

focus error signal or track error signal is carried out after the generation thereof.

The present invention is based on the object of proposing
5   a method for generating a corrected error signal for the operation of an apparatus for reading from and/or writing to an optical recording medium, and also a correspondingly configured apparatus, the compensated or corrected error signal being obtained independently of
10 the type and reflection property of the respectively scanned track of the optical recording medium.

This object is achieved according to the invention by means of a method having the features of Claim 1 and an
15 apparatus having the features of Claim 16. The subclaims each define preferred and advantageous embodiments of the present invention.

According to the invention it is proposed, for the
20 purpose of generating the respective error signal, which may be, in particular, a focus error signal or a track error signal, to generate primary and secondary scanning beams which scan adjacent tracks of the optical recording medium respectively used. From the reflected primary and
25 secondary scanning beams, primary-beam and secondary-beam error signals are respectively derived and normalized, the corrected or compensated error signal being obtained from the normalized primary-beam and secondary-beam error signals by means of weighted combination.
30

The error signals may be, in particular, focus error signals obtained according to the DFE method, or track error signals obtained according to the DPP method.

35 According to one variant of the invention, the primary-beam and secondary-beam error signals are normalized separately in each case. In accordance with another variant, joint normalization is provided for the

secondary-beam error signals. For both cases, according
to the invention, exemplary embodiments are proposed
which, by means of a corresponding choice of weighting
factor, enable complete compensation of the track-
5   position-dependent focus offset components (when
generating the focus error signal) or of the lens-
movement-dependent track offset component (when
generating the track error signal) even in the event of
varying reflection conditions of the respectively scanned
10 tracks. In this way, stable and offset-free focus or
track regulation is possible independently of the
reflection conditions of the respectively scanned optical
recording medium, the normalization proposed according to
the invention also obviating the need to determine the
15 weighting factor continuously using a suitable method.

Consequently, the present invention is a refinement of
the so-called DFE or DPP methods for forming an offset-
compensated focus error signal or track error signal,
20 respectively, with the present invention also being able
to be applied in particular to optical recording media
whose information tracks have been recorded on in part
and are blank in part. In particular, the present
invention can also be applied to optical recording media
25 whose information is stored both in depressions, i.e. in
"groove" tracks, and in elevations, i.e. in "land"
tracks, such as DVD-RAM discs for example.

The present invention is explained in more detail below
30 using preferred exemplary embodiments with reference to
the accompanying drawing. In this case, it is understood
that modifications within the scope of expert ability
likewise lie within the scope of the present invention.

35 Figure 1 shows a first exemplary embodiment of the
invention for generating an offset-compensated focus
error signal,

Figure 2 shows a second exemplary embodiment of the invention for generating an offset-compensated focus error signal,

5   Figure 3 shows a third exemplary embodiment of the invention for generating an offset-compensated focus error signal,

Figure 4 shows a fourth exemplary embodiment of the
10   invention for generating an offset-compensated focus error signal,

Figure 5 shows a simplified construction of an optical scanner for carrying out the DFE method or DPP method
15   according to the prior art, with this construction also being able to be applied to the present invention,

Figure 6 and Figure 7 show illustrations for illustrating the scanning of adjacent tracks of an optical recording
20   medium by a primary beam and two secondary beams,

Figure 8A shows a photodetector image upon application of the DFE method with the occurrence of a track-positioned-dependent focus offset component, but without the
25   occurrence of an actual focus error,

Figure 8B shows a photodetector image upon application of the DFE method with the occurrence of a focus error, but without the occurrence of a track-position-dependent
30   focus offset component,

Figure 9 shows a circuit arrangement according to the prior art for generating an offset-compensated focus error signal,
35

Figure 10A shows a photodetector image upon application of the DPP method with the occurrence of an actual track

error, but without the occurrence of a lens-movement-dependent track offset component,

Figure 10B shows the illustration of a photodetector image upon application of the DPP method with the occurrence of a lens-movement-dependent track offset component, but without the occurrence of an actual track error,

Figure 11 shows a circuit arrangement according to the prior art for generating an offset-compensated track error signal,

Figure 12 shows a fifth exemplary embodiment of the invention for generating an offset-compensated focus and track error signal, and

Figure 13 shows a sixth exemplary embodiment of the invention for generating an offset-compensated focus and track error signal.

As has already been mentioned previously, the focus error signal generated in accordance with the DFE method is composed, in practice, of the actual focus error and a track-position-dependent focus offset component. In order to generate an offset-compensated focus error signal DFE, the focus error signal CFE ("centre focus") generated in a manner dependent on the reflected primary beam is combined with the focus error signal OFE ("outer focus") generated in a manner dependent on the reflected secondary beams, in a weighted manner as follows:

$$DFE=CFE+g*OFE \qquad\qquad\qquad (1)$$

In this case, upon application of the photodetector structure having three four-quadrant detectors 10-12 which is shown in Figure 8, the following relationships hold true for the CFE signal and the OFE signal:

$$CFE = H' * ((A+C) - (B+D)) \tag{2}$$

$$OFE = L' * ((E+G) - (F+H)) + R' * ((I+K) - (J+L)) \tag{3}$$

In this case, g denotes the weighting factor, H' denotes the reflection factor of the track scanned by the primary beam, and L' and R' denote the reflection factors of the secondary tracks which are scanned by secondary beams and run to the left and right alongside the primary track scanned by the primary beam. A-L denote the output signals of the photodetector elements of the individual photodetectors 10-12 which are illustrated in Figure 8.

The positions of the secondary beams on the optical recording medium are chosen in such a way that the track-position-dependent focus offset components of the CFE signal and of the OFE signal are in antiphase. This is achieved, in theory, when the focus points of the secondary beams lie on the centre of the complementary track with respect to the track centre illuminated by the primary beam. If the weighting factor g is chosen correctly, then the track-position-dependent offset components of the primary beam and of the secondary beams cancel one another out after summation.

The actual deviations of the position of the objective lens with respect to the information layer of the optical recording medium will affect all three scanning beams equally. The resultant actual focus error signals of the CFE signal and of the OFE signal are therefore in phase and are added.

The weighting factor g can be defined only if the reflection factors H', L' and R' are identical or constant. However, as has been described previously, this is not always ensured. The invention therefore proposes normalizing the reflection factors in order to achieve

independence of the weighting factor g for the different reflection properties of the scanned tracks. Since both the actual focus error signal and the track-position-dependent focus offset components are proportional to the

5   reflection of the respectively scanned track, it is greatly advantageous to achieve independence from the instantaneous reflection of the respectively scanned track by means of normalization of the focus error components respectively generated by the three scanning

10 beams.

The reflection factor H' of the primary beam is proportional to the total quantity of light which strikes the photodetector 11 having the photodetector elements A-

15 D. Division by the summation signal of the individual photodetector elements makes it possible to achieve normalization for the primary beam:

$$CFEN=((A+C)-(B+D))/(A+B+C+D) \qquad (4)$$

20

In this case, CFEN denotes the normalized CFE signal. The summation signal (A+B+C+D) is proportional to the reflection factor H' of the primary beam. The same also applies correspondingly to the reflection factors L' and

25 R', i.e. the reflection factor L' is proportional to the summation signal (E+F+G+H) of the individual photodetector elements of the photodetector 10, while R' is proportional to the summation signal (I+J+K+L) of the individual photodetector elements of the photodetector

30 12. Consequently, it is possible to define a normalized OFE signal OFEN as follows:

$$OFEN=((E+G)-(F+H))/(E+F+G+H)+((I+K)-(J+L))/(I+J+K+L) \qquad (5)$$

35 From this there results a first exemplary embodiment for a corresponding circuit arrangement in which normalization is provided separately for each focus error signal derived from the three primary and secondary

beams, i.e. three dividers are required in order to normalize the respective components of the three beams, the following relationship following from the formulae (1) and (4), (5) for the normalized focus error signal
5   DFEN:

$$DFEN= ((A+C)-(B+D))/(A+B+C+D)+g*$$
$$(((E+G)-(F+H))/(E+F+G+H)+((I+K)-(J-L))/(I+J+K+L)), (6)$$

10 The normalization likewise compensates the differences in the intensities of the quantities of light reflected from the three tracks and also the total intensity of the scanning beam directed at the optical recording medium. The amplitudes of the focus error signals generated from
15 the three beams will thus be of the same size after normalization. This applies both to the track-position-dependent focus offset components and to the actual focus error components. In order to make the track-position-dependent focus offset components equal to zero, the
20 following relationship must therefore hold true:

$$DFEN_o=CFEN_o+g*OFEN_o=0; \quad OFEN_o = 2*CFEN_o \qquad (7)$$

In this case, the index "o" designates the respective
25 focus offset components of the normalized signals DFEN, CFEN and OFEN. Thus, with g = 0.5, complete compensation of the track-position-dependent focus offset component is achieved. In this case, the total focus error component will be twice as large as that of the primary beam alone.
30

A corresponding circuit arrangement for generating this normalized offset-compensated focus error signal DFEN is illustrated in Figure 1. As can be seen from Figure 1, firstly a normalized CEFN signal and a normalized OFEN
35 signal are generated in accordance with the above formulae (4) and (5), the OFEN signal being obtained from two intermediate signals OFE1 and OFE2. The offset-compensated focus error signal DFEN is obtained by

additive combination of these two normalized error signals CFEN and OFEN with g = 0.5.

A conventional circuit arrangement for generating the
5   focus error signal DFE in accordance with the above formulae (1)-(3) is illustrated for comparison in Figure 9.

Since, in the previously described optical arrangement,
10 the secondary beams are symmetrical with respect to the primary beam and illuminate the complementary tracks with respect to the tracks detected by the primary beam, their respective components for forming the actual focus error signal and the track-position-dependent focus offset is
15 identical in terms of magnitude. Therefore, the following also holds true:

$$OFE = (((E+G)-(F+H))+((I+K)-(J+L)))*(L'+R') \qquad (8)$$

20 The sum (L'+R') is once again proportional to the total quantity of light falling onto the two detectors 10 and 12. Therefore, the normalization is also valid for both secondary beam components together, so that the following holds true:
25

$$OFEN = (((E+G)-(F+H))+((I+K)-(J+L)))/(E+F+G+H+I+J+K+L) \quad (9)$$

It is apparent from this, for a second exemplary embodiment of the present invention, whose circuit
30 arrangement is illustrated in Figure 2, that only two dividers have to be used in order to normalize the respective components of the three beams in accordance with the following relationship:

35 $$DFEN = ((A+C)-(B+D))/(A+B+C+D)+g*$$
$$(((E+G)-(F+H))+((I+K)-(J+L)))/(E+F+G+H+I+J+K+L) \quad (10)$$

As a result of the normalization, the intensities of the light directed at the three tracks are likewise concomitantly normalized, but by joint normalization in the case of the secondary beams. The amplitudes of the error signals generated from the two contributions will thus be of the same size after normalization. This applies both to the track-position-dependent focus offset components and to the focus error components. In order to make the focus offset components equal to zero, the following must therefore hold true for g:

$$DFEN_o=CFEN_o+g*OFEN_o=0; \quad OFEN_o=DFEN_o \qquad (11)$$

Consequently, with $g = 1$, complete compensation of the track-position-dependent focus offset component is achieved. In this case, the total focus error component will be twice as large as that of the primary beam.

The above description makes it clear that, with the aid of the present invention, the individual contributions which enter into the offset-compensated focus error signal can be made independent of the reflection properties of the respectively scanned tracks of the optical recording medium.

Likewise, independence from the instantaneous reflection of the respectively scanned track can be achieved during the generation of an offset-compensated track error signal in accordance with the DPP method by means of normalization of the track error components respectively read.

The conventional approach for generating the offset-compensated DPP signal according to the prior art is as follows:

$$DPP=CPP-k*OPP \qquad (12)$$

In this case, the CPP signal designates the track error signal generated in a manner dependent on the reflected primary beam, while the OPP signal represents the track error signal obtained in a manner dependent on the

5   reflected secondary beams. k denotes the weighting factor for the weighted combination of the CPP signal and of the OPP signal.

The CPP signal and the OPP signal can be expressed as a

10   function of the reflection factors of the respectively scanned track of the optical recording medium, assuming the photodetector structure shown in Figure 10, as follows:

15     $CPP = H' * ((A+D) - (B+C))$ (13)

    $OPP = L' * (E2 - E1) + R' * (F2 - F1)$ (14)

In this case, H' denotes the reflection factor of the

20   track scanned by the primary beam, while L' and R' denote the reflection factors of the tracks scanned by the secondary beams to the left and right of the primary track scanned by the primary beam. As is shown in Figure 10, a four-quadrant photodetector having photodetector

25   elements A-D is used for detecting the primary beam, while respective photodetectors 10 and 12 having only two photodetector elements E1 and E2, and respectively F1 and F2, are used for detecting the reflected secondary beams.

30   The positions of the secondary beams on the optical recording medium are chosen in such a way that the trace-error-proportional components of the CPP signal and of the OPP signal are in antiphase. Those components of the CPP signal and of the OPP signal which are caused by the

35   movement of the objective lens from the optical axis, i.e. the lens-movement-proportional components, are in phase, however. If the factor k is chosen correctly, then these lens-movement-proportional components of the CPP

signal and of the OPP signal are mutually cancelled out during subtraction. Therefore, the factor k is to be chosen in such a way that the following holds true:

5        $DPP_1 = CPP_1 - k*OPP_1 = 0$ (15)

The index "1" denotes the lens-movement-proportional or lens-movement-dependent component of the individual signals.

10

The value for the weighting factor k can be defined only if the reflection factors H', L' and R' are identical or constant. As has already been described, however, this is not always ensured. According to the invention, however,
15   independence of the weighting factor k from the different reflection properties of the respectively scanned tracks of the optical recording medium is achieved by means of normalization.

20   As has already been described, the reflection factor H' of the primary beam is proportional to the total quantity of light which strikes the photodetector 11 having the photodetector elements A-D. Consequently, analogously to the previously described case of normalization of the DFE
25   signal, by division by the summation signal of the individual photodetector elements A-D, normalization for the primary beam can be achieved as follows:

        $CPPN = ((A+D)-(B+C))/(A+B+C+D)$ (16)
30

In this case, CPPN denotes the normalized CPP signal. A normalized OPP signal OPPN can likewise be defined for the reflection factors L' and R':

35        $OPPN = (E2-E1)/(E1+E2)+(F2-F1)/(F1+F2)$ (17)

Consequently, from the formulae (12), (16) and (17), there follows for the generation of a normalized DPP signal DPPN:

5        $DPPN = ((A+D)-(B+C))/(A+B+C+D) -$
         $k*((E2-E1)/(E1+E2)+(F2-F1)/(F1+F2))$ (18)

The normalization likewise concomitantly normalizes the differences in the intensities of the light directed at
10   the three tracks. The amplitudes of the error signals generated from the three beams will thus be of the same size after normalization. From the formula (15), it follows for the lens-movement-dependent component where

15      $OPP_1 = 2*CPP_1,$ (19)

that, for k = 0.5, complete compensation of the lens-movement-dependent component can be achieved. In this case, the track-error-dependent component will be twice
20   as large as that of the primary beam alone.

Figure 3 illustrates an exemplary embodiment – corresponding to the formula (18) – for a circuit arrangement according to the invention for generating the
25   offset-compensated normalized track error signal DPPN, three dividers being used separately in order to normalize the individual beams.

A conventional circuit arrangement according to the prior
30   art for generating the track error signal DPP in accordance with the above formulae (12)-(14) is illustrated for comparison in Figure 11. As can be seen from Figure 11, the CPP and OPP signals are not normalized in accordance with the prior art. Therefore,
35   it is necessary for the weighting factor k to be · continuously adapted to the reflection properties of the respectively scanned tracks.

Since, in the case of the previously mentioned optical arrangement, the secondary beams are arranged symmetrically with respect to the primary beam, their respective components for forming the track error signal
5   has the same magnitude. The following therefore holds true:

$$OPP=((E2+F2)-(E1+F1))*(L'+R') \qquad (20)$$

10   The sum (L'+R') is once again proportional to the total quantity of light falling onto the detector elements E1, E2, F1 and F2. Therefore, the following normalization valid for both secondary beam components can be carried out:
15

$$OPPN=((E2+F2)-(E1+F1))/(E1+E2+F1+F2) \qquad (21)$$

The following emerges from this for the normalized error signal DPPN:
20

$$DPPN= ((A+D)-(B+C))/(A+B+C+D)-$$
$$k*(((E2+F2)-(E1+F1))/(E1+E2+F1+F2)) \qquad (22)$$

The normalization likewise concomitantly normalizes the
25   differences in the intensities of the light directed at the three tracks. The amplitudes of the error signals generated from the three beams will thus be of the same size after normalization. For complete compensation of the lens-movement-dependent component, the following
30   relationship holds true:

$$DPP_1=CPP_1-k*OPP_1=0; OPP_1 = CPP_1 \qquad (23)$$

Consequently, with k = 1, complete compensation of the
35   lens-movement-dependent component of the track error signal DPPN can be achieved. In this case, the track-error-dependent component is twice as large as that of the primary beam alone.

A corresponding circuit arrangement for generating the corrected or compensated track error signal DPPN in accordance with the above formula (22) is illustrated in

5   Figure 4. As can be seen from Figure 4, only two dividers are required for generating the normalized signal CPPN or the normalized signal OPPN, which are subsequently combined by weighted subtraction with k = 1 to form the compensated track error signal DPPN.

10

It goes without saying that the above DPP method can also be employed if the photodetectors in each case have four light-sensitive areas. In this case, corresponding summation signals are still formed by two respective

15   detector areas.

Furthermore, it should be noted that the previously described weighting factors g and k are valid only when component tolerances and other tolerances do not have to

20   be taken into account. By way of example, an error source might be the normalization elements used in Figures 1-4, since divisions are difficult to realize using analogue technology. Consequently, the previously described weighting factors apply only to the ideal case. In order

25   to compensate component tolerances, if appropriate a departure is made from these values to a greater or lesser extent.

Likewise, it is possible, in contrast to the exemplary

30   embodiments illustrated in Figures 1-4, to apply the weighting factors g and k to the primary beam signals CFEN and CPPN, respectively, as well, so that the normalized focus error signal DFEN is calculated in accordance with the following formula:

35

$$DFEN=g'*CFEN+OFEN \text{ where } g'=1/g \qquad (24)$$

The normalized track error signal DPPN is then
analogously calculated in accordance with the following
formula:

5   DPPN=k'*CPPN-OPPN where k'=1/k   (25)

In the case of the previously described exemplary
embodiments illustrated in Figures 1-4, the normalization
was in each case employed separately in order to form a
10   focus or track error signal. However, the circuitry
outlay can be reduced if the normalization is employed
for forming both the focus and the track error signal,
since then the summation for obtaining the respective
normalization signal can be used jointly for both signal
15   paths. Figure 12 and Figure 13 illustrate corresponding
exemplary embodiments, Figure 12 showing an exemplary
embodiment corresponding to Figures 1 and 3 in which the
secondary scanning beams are normalized separately in
each case (weighting factors g, k = 0.5), while Figure 13
20   shows an exemplary embodiment corresponding to Figures 2
and 4 with joint normalization of the secondary scanning
beams (weighting factors g, k = 1).

The illustrations of Figure 12 and Figure 13 also reveal
25   how the DPP method can be applied to three photodetectors
10-12 each having four light-sensitive areas. In this
case, the two photodetector elements E1, E2 and F1, F2 of
the embodiments described above correspond to the
photodetector elements F and G, E and H and, respectively
30   J and K, I and L.

Consequently, according to the invention, a corrected or
compensated focus error signal DFEN or track error signal
DPPN is obtained by primary and secondary scanning beams
35   incident on adjacent tracks of an optical recording
medium 7 being generated and the primary and secondary
scanning beams reflected from the optical recording
medium being detected in order to derive therefrom

primary-beam and secondary-beam focus error signals CFE, OFE or primary-beam and secondary-beam track error signals CPP, OPP, which are subsequently normalized in order to obtain the compensated focus error signal DFEN error track or signal DPPN from the normalized primary-beam and secondary-beam error signals CFEN, OFEN; CPPN, OPPN by means of weighted combination. As a result of the normalization, the corrected or compensated circuit error signal DFEN or track error signal DPPN can be generated independently of the reflection properties of the respectively scanned track.

An apparatus according to the invention is suitable for reading from and/or writing to optical recording media which have, in terms of their physical properties, different track types arranged adjacent to one another. The apparatus has a beam generation unit for generating primary and secondary scanning beams incident on adjacent tracks of a recording medium, a photodetector having multi-zone detector elements for detecting the primary and secondary scanning beams reflected from the recording medium, and an evaluation circuit for forming a corrected error signal by weighted combination of primary-beam and secondary-beam error signals formed from the detected signals of the primary and secondary scanning beams. In this case, the evaluation circuit has normalizing means for normalizing primary-beam and secondary-beam error signals.

As already mentioned, for all the above considerations it was assumed in a simplification that the intensities of the three scanning beams considered are identical when impinging on the photodetector unit 9. Therefore, the compensation factors g and k specified apply only if this simplification is employed.

In practice, however, the intensity of the secondary beams is dependent on their track position, on the

reflection of the scanned track and also on the properties of the optical diffraction grating 3 and is weaker than the intensity of the primary beam, so that the intensity of the secondary beams must be scaled
5   correspondingly with respect to the primary beam intensity. Ideally, this is done by normalization. To that end, the signals derived from the reflected beams are normalized. The signals CPP and OPP or, alternatively, the individual signals OPP1 and OPP2 are
10 normalized by these signals being divided by the summation signals which are proportional to the quantity of light respectively taken up by the detector areas.

As described above, it is necessary to adapt the
15 weighting factor g or k to the secondary track spacings. By way of example, if the variant shown in Figure 3 is taken as a basis, then the signal amplitudes of the signal DPPN is dependent on the setting of the compensation factor k.
20

The variant of the embodiments in accordance with Figures 3 and 4 which is shown in Figures 14 and 15, respectively, relates to the weighting between primary beam and secondary beams. By way of example, the
25 weighting factor k for the secondary beam signal is advantageously replaced by two weighting factors k' and 1-k' which act on the primary and secondary beam signals, where k' can be calculated from k according to the following relationship:
30

$$k' = \frac{k}{(1 + k)}$$

The effects achieved by splitting the weighting factor k into two weighting factors dependent on k' is that the
35 amplitude of the normalized signal DPPN is independent of the weighting factor to be set in each case. Correspondingly, this formula can also be applied to the weighting factor g for forming the signal DFEN. The

factors g and k are chosen for example in the manner described with respect to Figure 3 and Figure 4.

PATENT CLAIMS

1. Method for generating a corrected error signal for
    the operation of an apparatus for reading from
    and/or writing to an optical recording medium,
    primary and secondary scanning beams (13-15)
    incident on adjacent tracks of the recording medium
    (7) being generated and the primary and secondary
    scanning beams reflected from the recording medium
    (7) being detected, and
    primary-beam and secondary-beam error signals (CFE,
    OFE; CPP, OPP) being derived from the detected
    reflected primary and secondary scanning beams and
    being combined with one another in a weighted manner
    in order to form a corrected error signal,
    characterized
    in that the primary-beam and secondary-beam error
    signals (CFE, OFE; CPP, OPP) are normalized before
    the corrected error signal (DFEN; DPPN) is formed by
    weighted combination therefrom.

2. Method according to Claim 1,
    characterized
    in that the primary-beam error signal (CFE; CPP) and
    the secondary-beam error signals (OFE; OPP) are in
    each case normalized separately.

3. Method according to Claim 1,
    characterized
    in that the secondary-beam error signals (OFE; OPP)
    are normalized together.

4. Method according to one of the preceding claims,
    characterized
    in that the primary-beam and secondary-beam error
    signals (CFE, OFE) are focus error signals which are
    normalized in order subsequently to obtain a

corrected focus error signal (DFEN) by means of weighted combination.

5. Method according to Claim 4,
   characterized
   in that the corrected focus error signal DFEN is obtained from the normalized primary-beam focus error signal CFEN and the normalized secondary-beam focus error signal OFEN in accordance with the following relationship:
   DFEN = CFEN+g*OFEN,
   where g denotes a weighting factor.

6. Method according to Claims 2 and 5,
   characterized
   in that a primary scanning beam (14) and two secondary scanning beams (13, 15) are generated and the primary and secondary scanning beams reflected from the optical recording medium (7) are detected by photodetectors (10-12) each having four photodetector elements, and
   in that the corrected focus error signal DFEN is obtained in accordance with the following relationship:
   DFEN= ((A+C)-(B+D))/(A+B+C+D)+g*
          (((E+G)-(F+H))/(E+F+G+H)+((I+K)-(J-L))/(I+J+K+L)),
   where A-D denotes the output signals of the photodetector elements of the photodetector (11) which detects the reflected primary scanning beam, while E-H and I-L denote the output signals of the photodetector elements of the photodetectors (10, 12) which detect the reflected secondary scanning beams.

7. Method according to Claim 6,
   characterized
   in that g = 0.5 is chosen for the weighting factor.

8. Method according to Claims 3 and 5,
    characterized
    in that a primary scanning beam (14) and two
    secondary scanning beams (13, 15) are generated and
5   the primary and secondary scanning beams reflected
    from the optical recording medium (7) are detected
    by photodetectors (10-12) each having four
    photodetector elements, and
    in that the corrected focus error signal DFEN is
10 obtained in accordance with the following
    relationship:
    DFEN= ((A+C)-(B+D))/(A+B+C+D)+g*
          (((E+G)-(F+H))+((I+K)-(J+L)))/(E+F+G+H+I+J+K+L),
    where A-D denote the output signals of the
15 photodetector elements of the photodetector (11)
    which detects the reflected primary scanning beam,
    while E-H and I-L denote the output signals of the
    photodetector elements of the photodetectors (10,
    12) which detect the reflected secondary scanning
20 beams.

9. Method according to Claim 8,
    characterized
    in that g = 1 is chosen for the weighting factor.
25

10. Method according to one of Claims 1-3,
    characterized
    in that the primary-beam and secondary-beam error
    signals (CPP, OPP) are track error signals which are
30 normalized in order to obtain a corrected track
    error signal (DPPN) by means of weighted
    combination.

11. Method according to Claim 10,
35 characterized
    in that the corrected track error signal DPPN is
    obtained from the normalized primary-beam track
    error signal CPPN and the normalized secondary-beam

error signal OPPN in accordance with the following
relationship:

DPPN = CPPN-k*OPPN,

where k denotes a weighting factor.

12. Method according to Claims 2 and 11,
characterized
in that a primary scanning beam (14) and two
secondary scanning beams (13, 15) are generated and
the secondary scanning beams reflected from the
optical recording medium (7) are each detected by
photodetectors (10, 12) having two photodetector
elements, while the primary scanning beam reflected
from the optical recording medium (7) is detected by
a photodetector (11) having four photodetector
elements, and
in that the corrected track error signal DPPN is
obtained in accordance with the following
relationship:

$$DPPN= ((A+D)-(B+C))/(A+B+C+D)-$$
$$k*((E2-E1)/(E1+E2)+(F2-F1)/(F1+F2)),$$

where A-D denotes the output signals of the
photodetector elements of the photodetector (11)
provided for detection of the reflected primary
scanning beam, while E1 and E2, and respectively F1
and F2, denote the output signals of the
photodetector elements of the photodetectors (10,
12) provided for detection of the reflected
secondary scanning beams.

13. Method according to Claim 12,
characterized
in that k = 0.5 is chosen for the weighting factor.

14. Method according to Claims 3 and 11,
characterized
in that a primary scanning beam (14) and two
secondary scanning beams (13, 15) are generated and

the secondary scanning beams reflected from the optical recording medium (7) are each detected by photodetectors (10, 12) having two photodetector elements, while the primary scanning beam reflected
5   from the optical recording medium (7) is detected by a photodetector (11) having four photodetector elements, and
in that the corrected track error signal DPPN is obtained in accordance with the following
10   relationship:

DPPN= ((A+D)-(B+C))/(A+B+C+D)-
        k*(((E2+F2)-(E1+F1))/(E1+E2+F1+F2)),

where A-D denotes the output signals of the photodetector elements of the photodetector (11)
15   provided for detection of the reflected primary scanning beam, while E1 and E2, and respectively F1 and F2, denote the output signals of the photodetector elements of the photodetectors (10, 12) provided for detection of the reflected
20   secondary scanning beams.

15.   Method according to Claim 14,
       characterized
       in that k = 1 is chosen for the weighting factor.
25

16.   Apparatus for reading from and/or writing to an optical recording medium,
       having a beam generation unit (1-3) for generating primary and secondary scanning beams (13-15)
30   incident on adjacent tracks of the optical recording medium (7),
       having a photodetector unit (9) for detecting the primary and secondary scanning beams reflected from the optical recording medium (7) and
35   having an evaluation unit (16) for forming a corrected error signal by weighted combination of primary-beam and secondary-beam error signals (CFE,

OFE; CPP, OPP) derived from the detected reflected
primary and secondary scanning beams,
characterized
in that the evaluation unit (16) has normalization
5   means for normalizing the primary-beam and
secondary-beam error signals (CFE, OFE; CPP, OPP)
before the weighted combination thereof to form the
corrected error signal (DFEN; DPPN).

10   17. Apparatus according to Claim 16,
characterized
in that the normalization means are configured for
in each case separate normalization of the primary-
beam error signal (CFE; CPP) and of the secondary-
15   beam error signals (OFE; OPP).

18. Apparatus according to Claim 16,
characterized
in that the normalization means are configured in
20   such a way that the secondary-beam error signals
(OFE; OPP) are normalized together.

19. Apparatus according to one of Claims 16-18,
characterized
25   in that the evaluation unit is configured for
generating primary-beam and secondary-beam focus
error signals (CFE, OFE) and for generating a
corrected focus error signal (DFEN) by weighted
combination of the normalized primary-beam and
30   secondary-beam focus error signals (DFEN, OFEN).

20. Apparatus according to Claim 19,
characterized
in that the evaluation unit (16) or the
35   normalization means are configured for carrying out
a method according to one of Claims 5-9.

21. Apparatus according to one of Claims 16-18,

characterized

in that the evaluation unit (16) is configured for generating primary-beam and secondary-beam track error signals (CPP, OPP) and for generating a corrected track error signal (DPPN) by weighted combination of the normalized primary-beam and secondary-beam track error signals (CPPN, OPPN).

22. Apparatus according to Claim 21,
    characterized
    in that the evaluation unit (16) or the normalization means are configured for carrying out a method according to one of Claims 11-15.

Fig.1

Fig.2
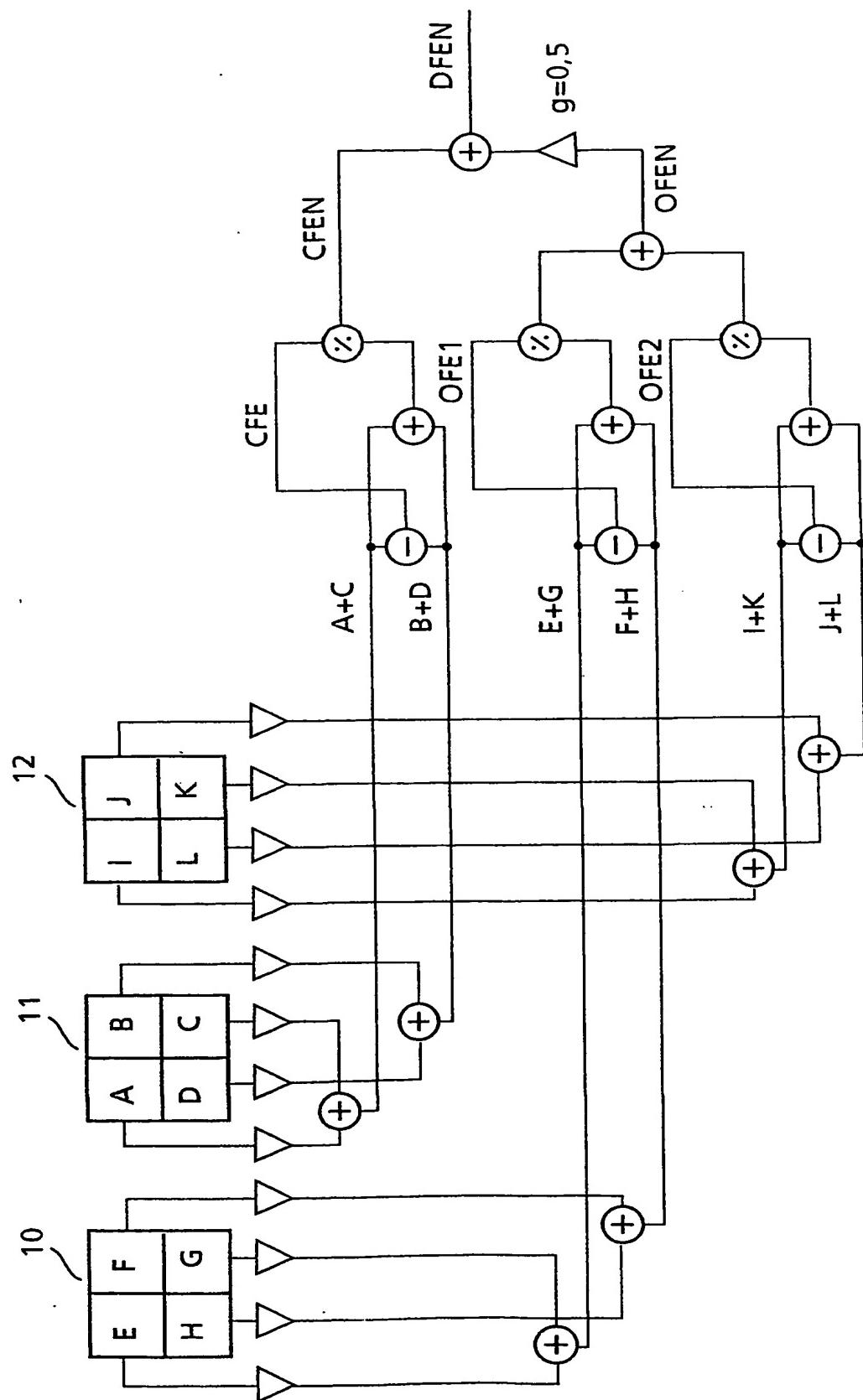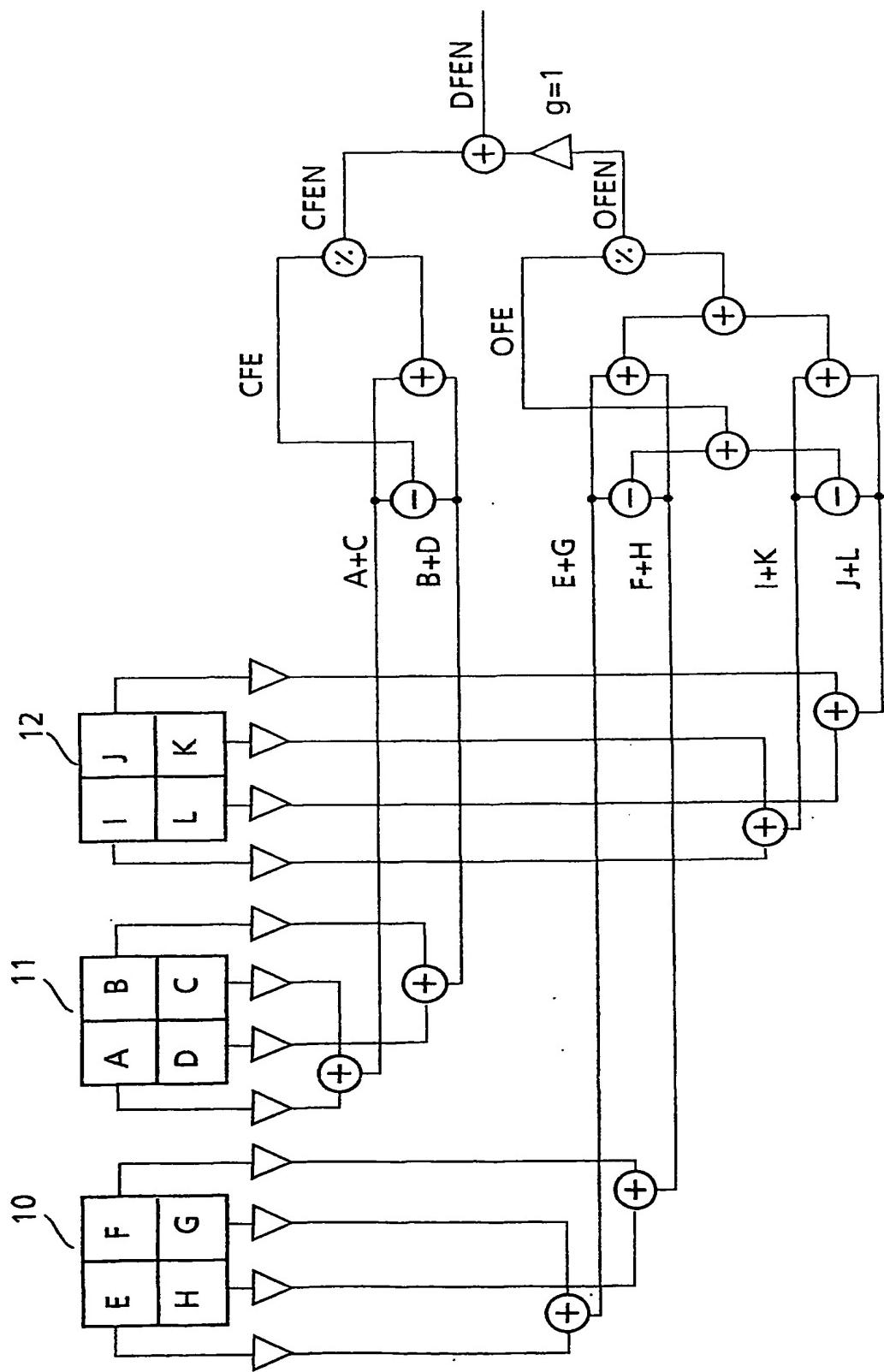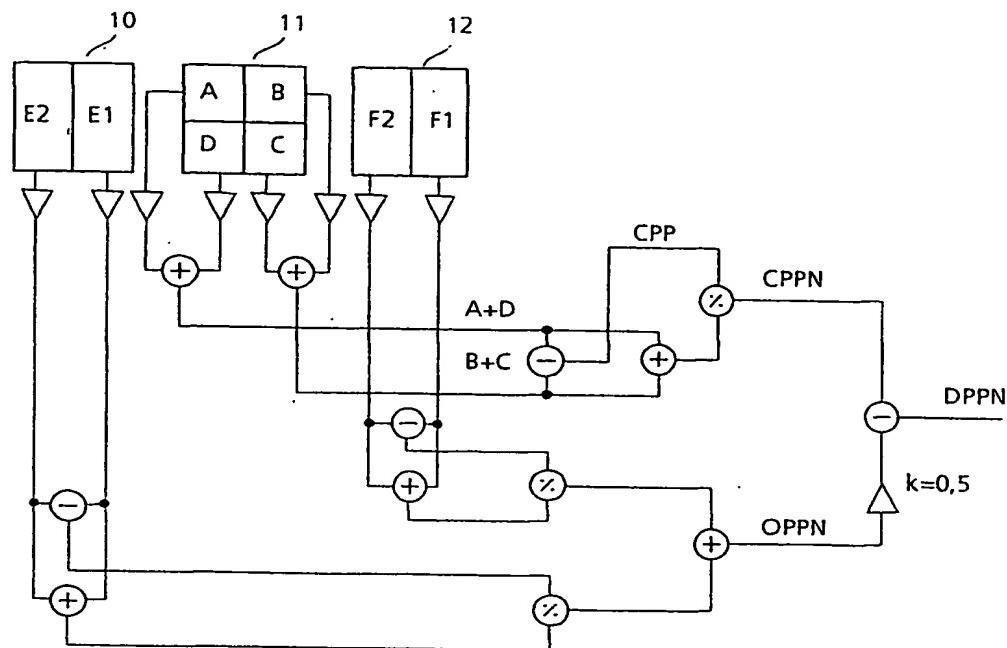
Fig.3
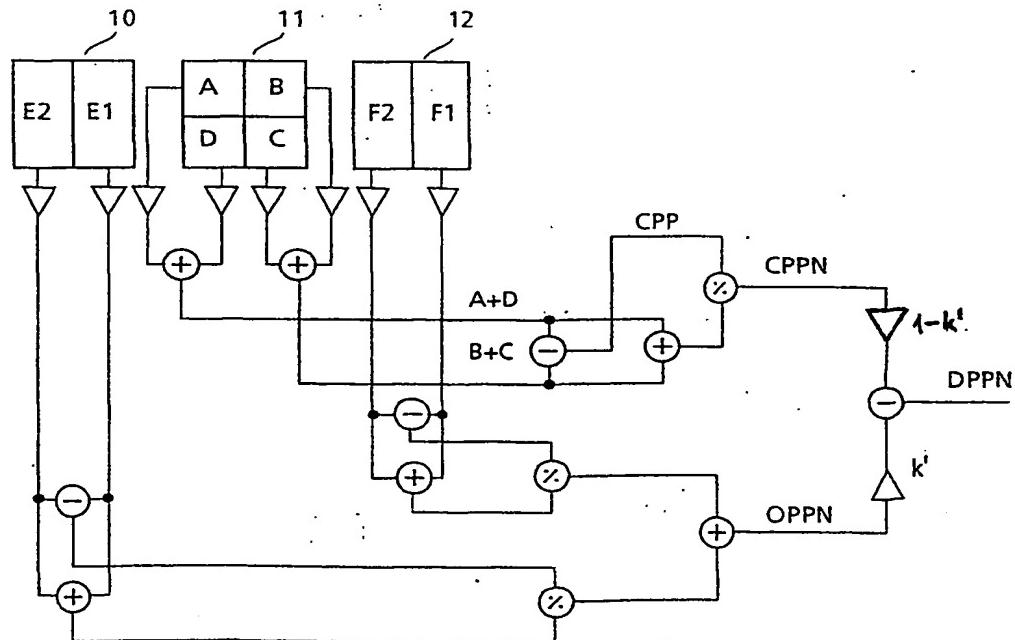
Fig.14
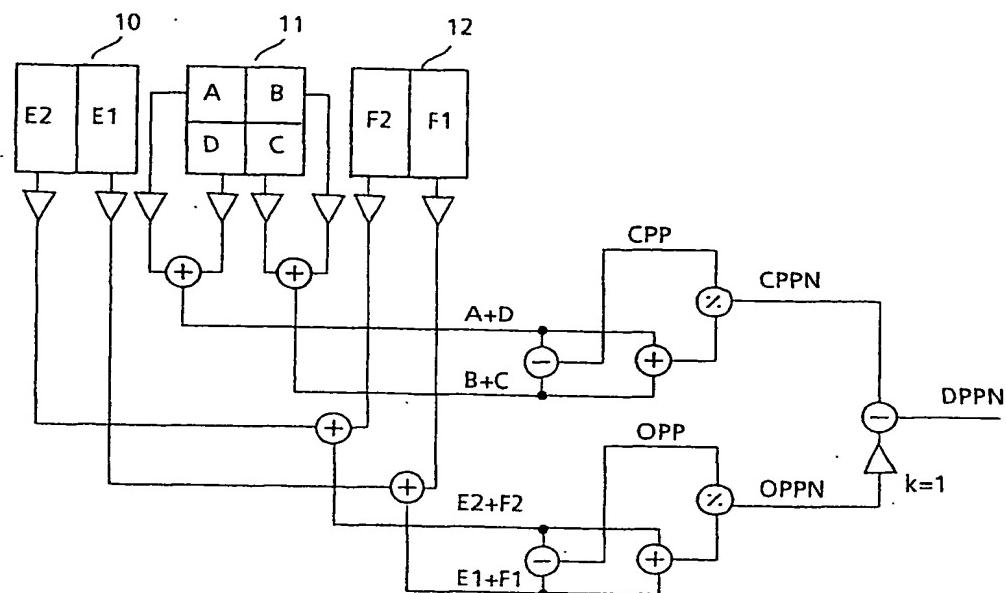
Fig.4
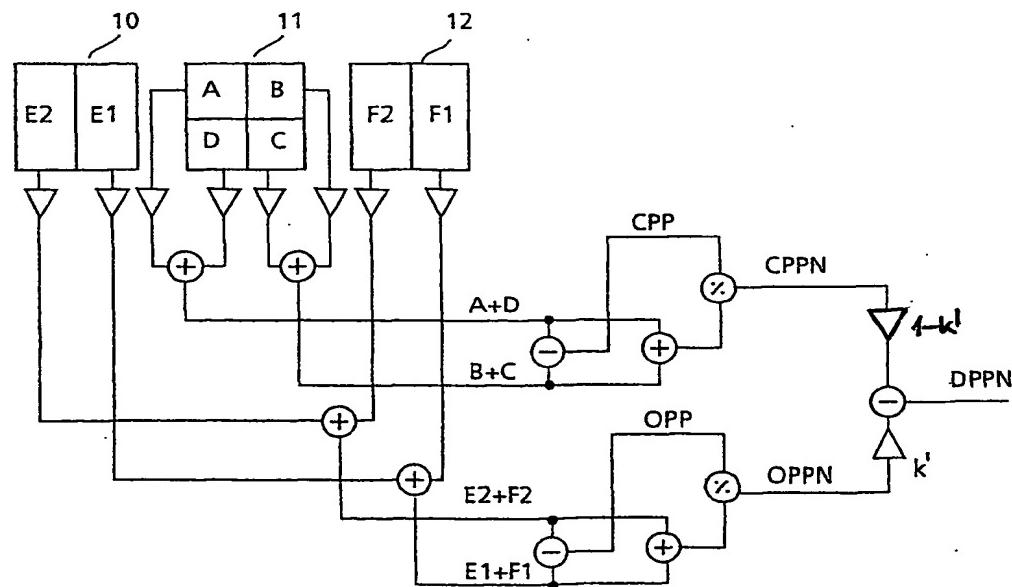

**Fig.15**

Fig.5

Fig.8

Fig.6

Gr　　　La　　　Gr　　　La
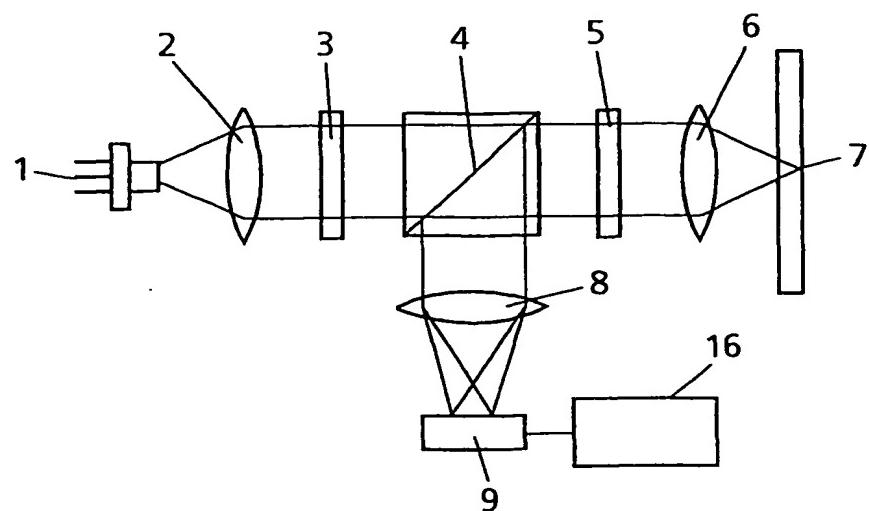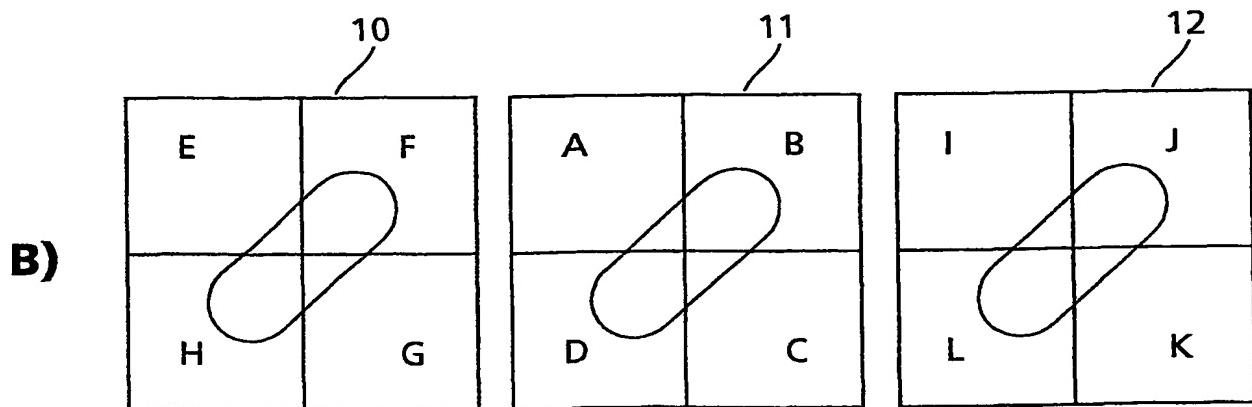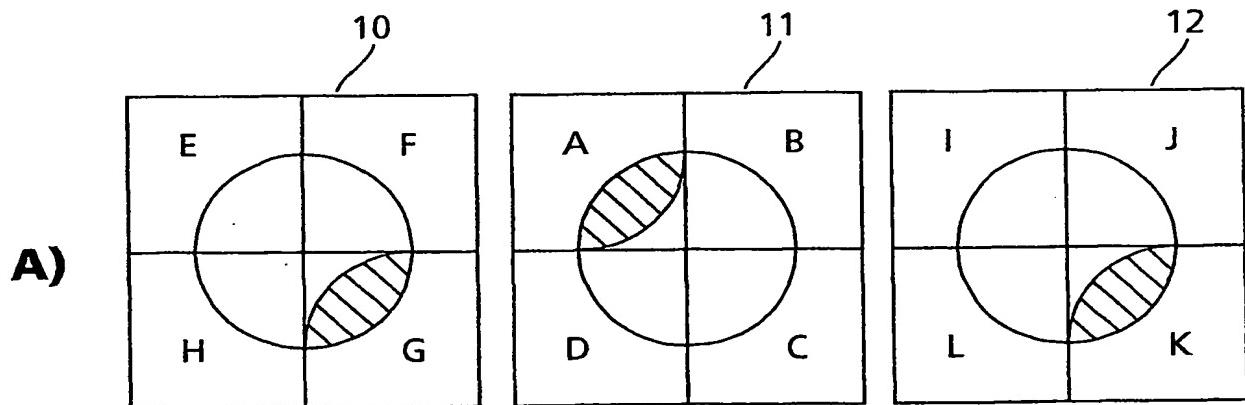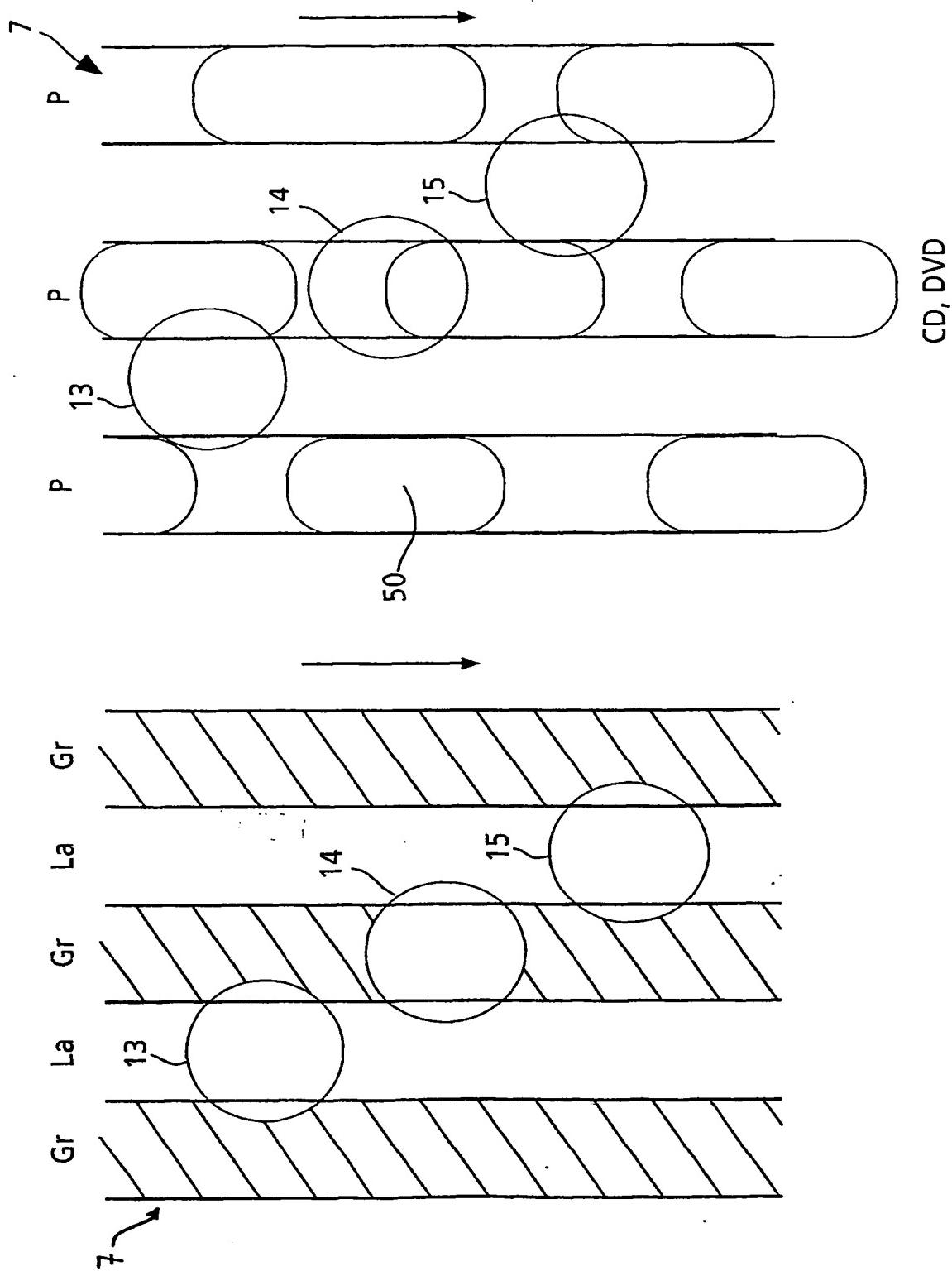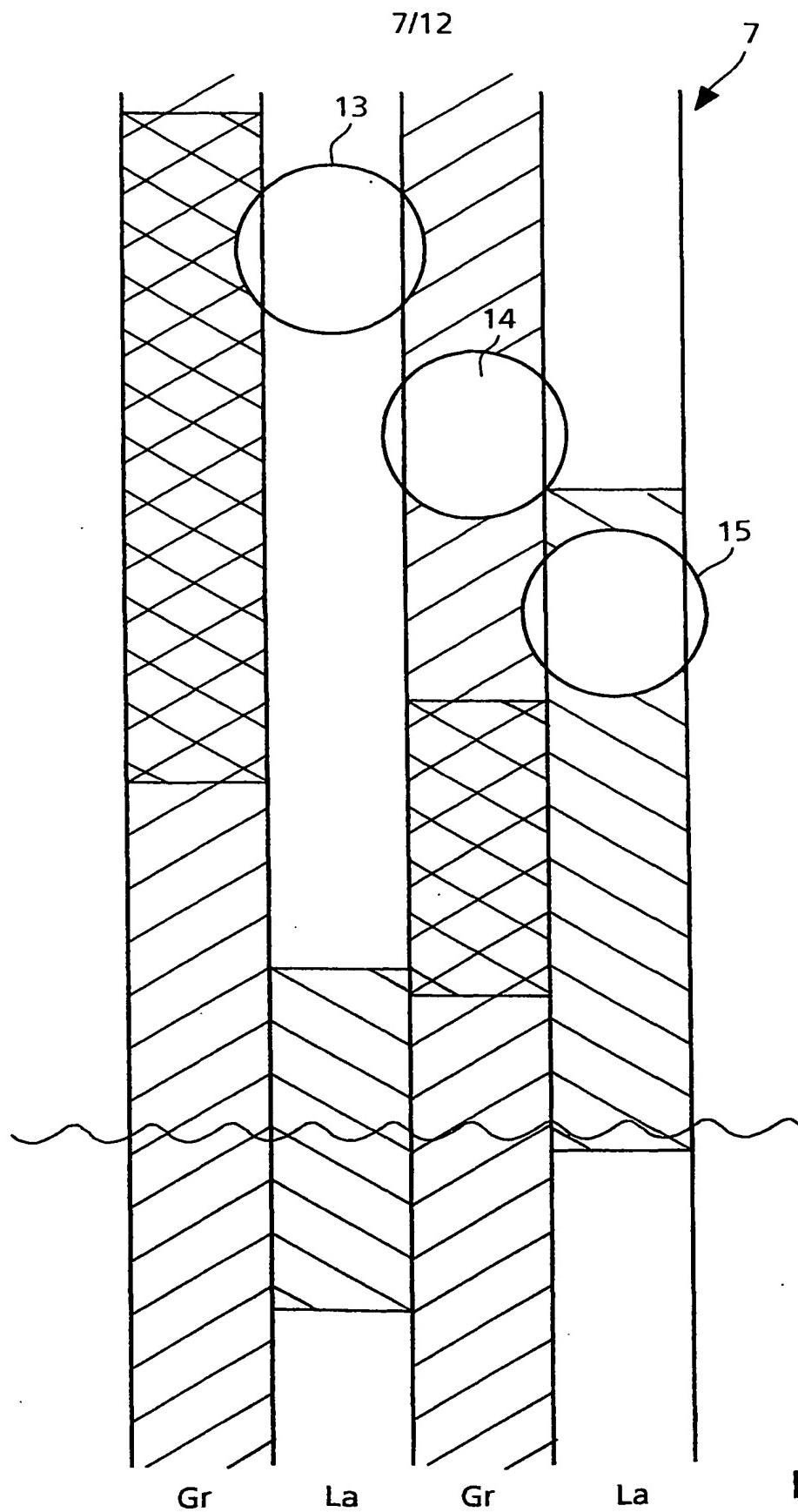
Fig.7
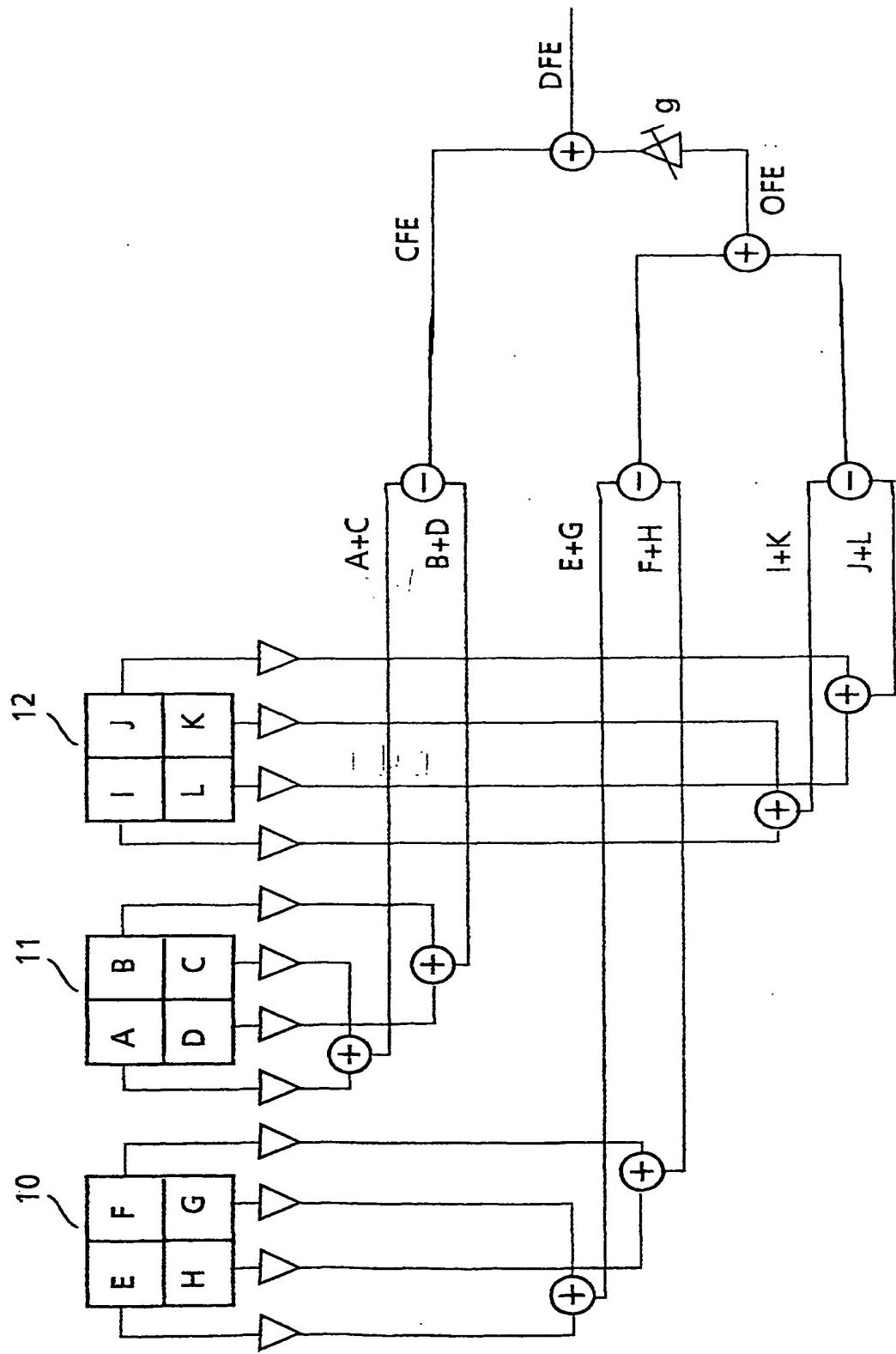
Fig.9 (PRIOR ART)
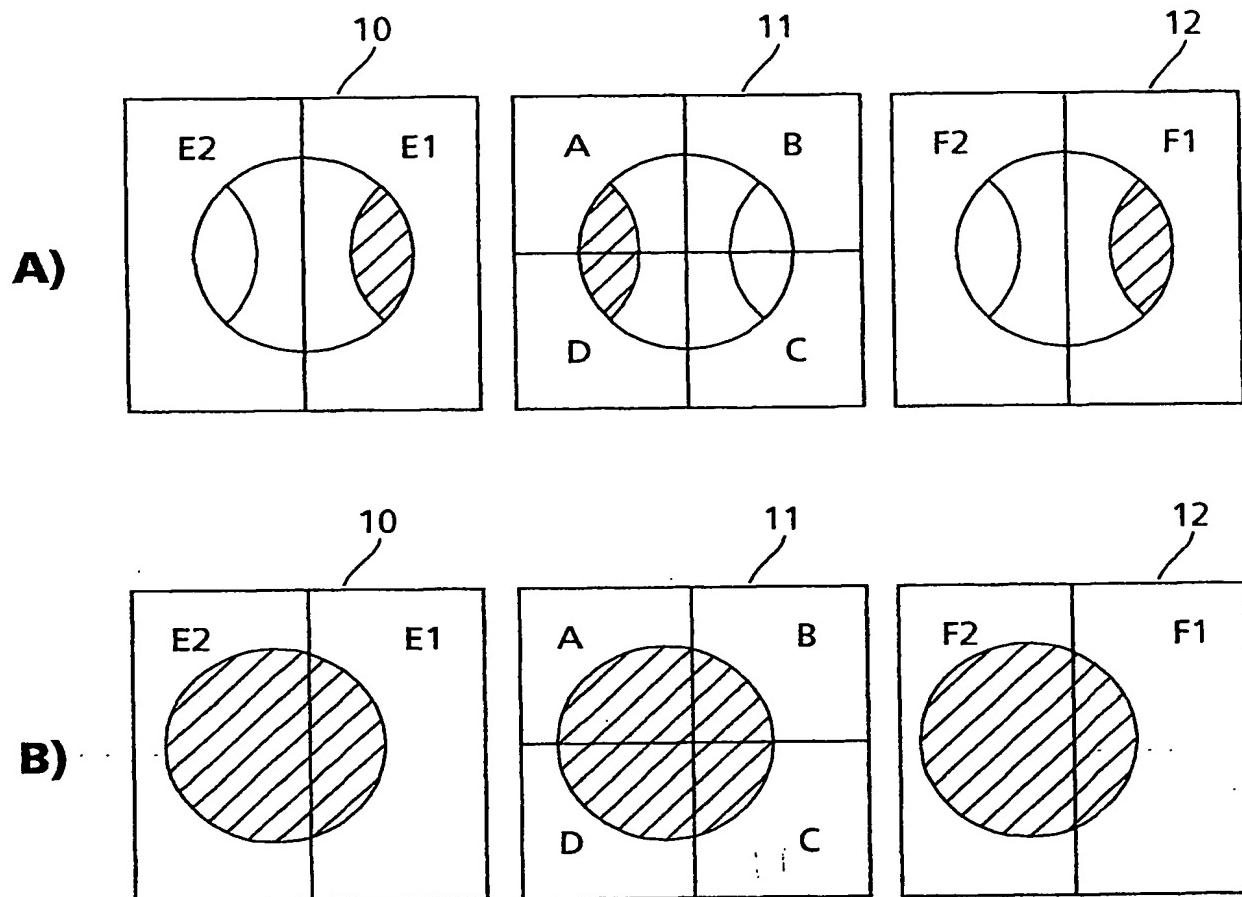
Fig.10
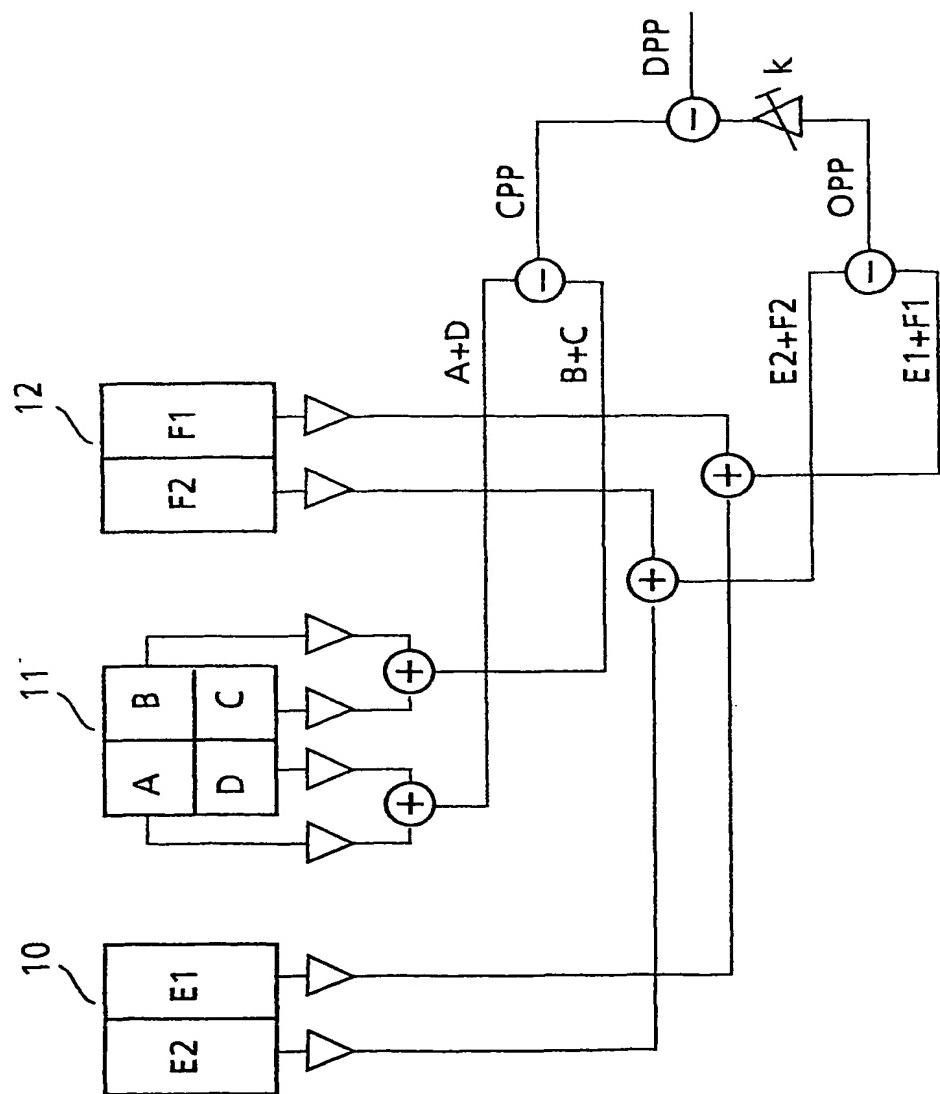
Fig.11 (PRIOR ART)
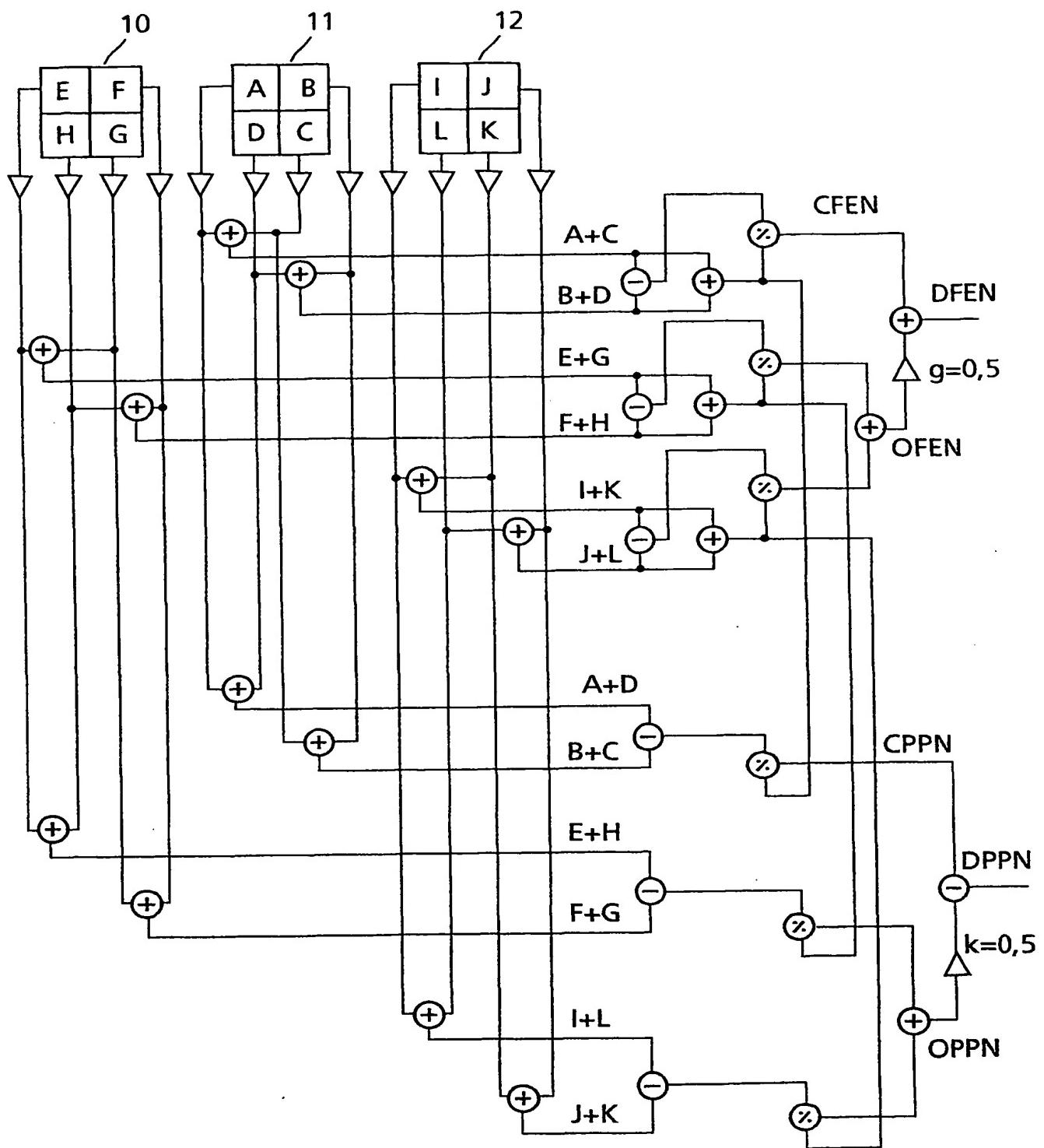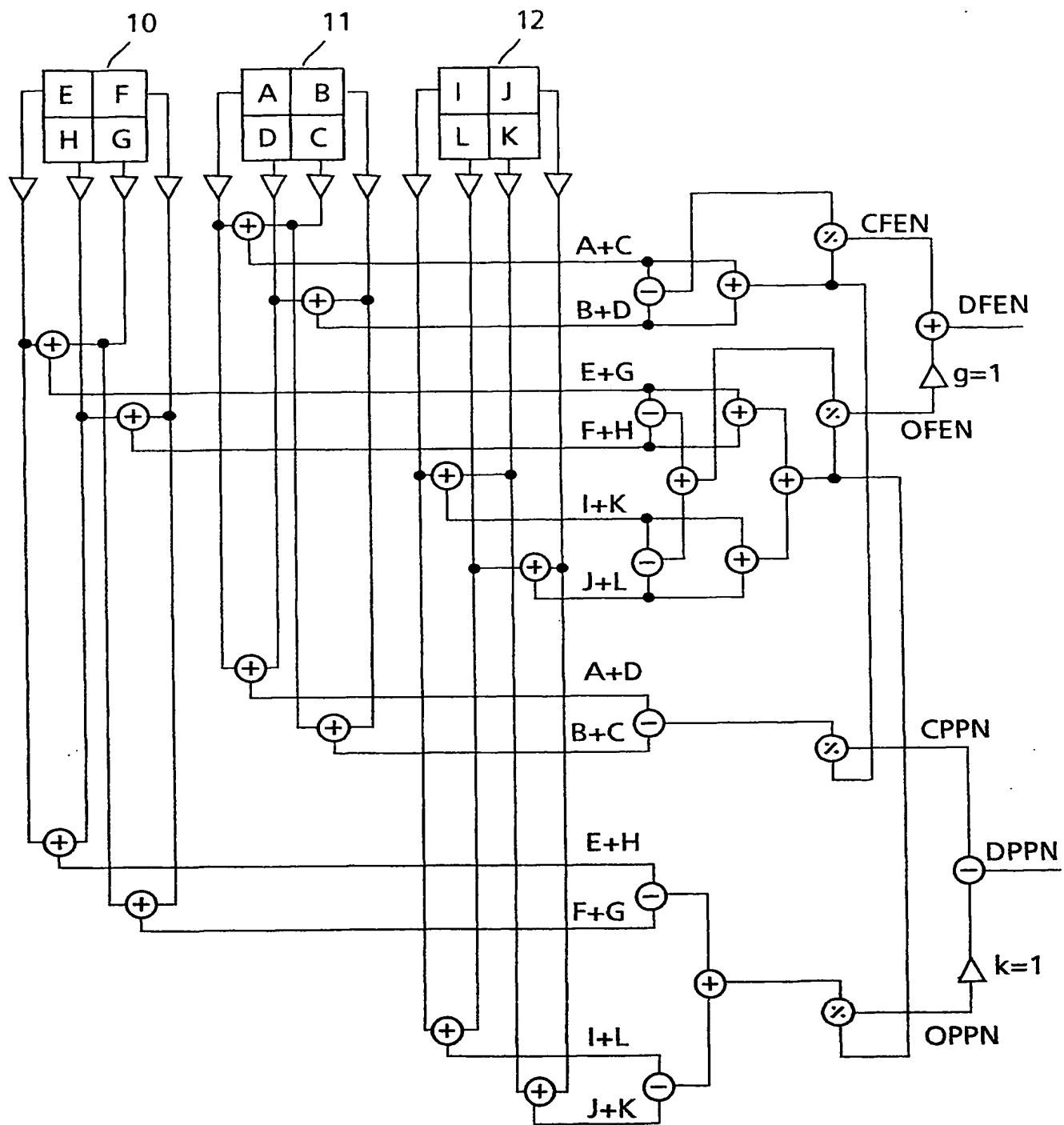
Fig.12

Fig.13

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   G11B7/09

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7   G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 10, 17 November 2000 (2000-11-17) & JP 2000 187857 A (SHARP CORP), 4 July 2000 (2000-07-04) abstract	1,2,10, 11,16, 21,22
A		12,13
A	EP 0 829 857 A (NIPPON ELECTRIC CO) 18 March 1998 (1998-03-18) abstract; figure 3	1,4,16, 19
A	EP 0 512 616 A (PHILIPS NV) 11 November 1992 (1992-11-11) abstract; figure 3	1,10;16, 21
	-/--	

[X] Further documents are listed in the continuation of box C.	[X] Patent family members are listed in annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 December 2001	07/12/2001
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